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VEGETATION AND FOREST PRODUCTIVITY SYNCRUDE LEASE 22

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Hardy Associates (1978) Ltd.

FOREWORD

This monograph describes the vegetation and forest productivity of Syncrude's Lease 22 area. It complements a similar study conducted on Syncrude's Lease 17 in 1977 (Syncrude Environmental Research Monograph 1977-6).

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VEGETATION AND FOREST PRODUCTIVITY
SYNCRUDE LEASE 22

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ABSTRACT

Syncrude Canada Ltd. is producing synthetic crude oil from a surface mine on the eastern portion of Syncrude Lease 17. Hardy Associates was commissioned to describe and map the vegetation types and to assess forest productivity on the adjacent Lease 22 in order to add to Syncrude's baseline environmental knowledge of this lease area. Eleven major vegetation types were identified and are mapped at a scale of 1:20 000. Aspen-white spruce was the dominant vegetation type covering nearly 28% of the 19 600 ha study area. The second most abundant vegetation type was black spruce-Labrador tea (24%) and the third was aspen-birch at 15%. The remaining 33% of the area was occupied by a complex pattern of willow reed-grass, white spruce-aspen, black spruce-feathermoss, aspen-jack pine, sedge-reed grass, balsam poplar-alder, white spruce-balsam fir and river alder-tall willow types. The average mean annual increment for the lease is 1.4 m^3/ha yr (or class 6), with the aspen-white spruce type providing the major portion of the productivity at class 5, and the black spruce-Labrador tea type the least at class 7.

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1.0 INTRODUCTION

Syncrude Canada Ltd. has undertaken a study to establish baseline information on the present vegetation and forest productivity of Lease 22. The study area is located on the west side of the Athabasca River immediately north of Lease 17 which contains the current mining and upgrading facilities (Figure 1).

1.1 STUDY OBJECTIVES

The major objective of this study is to provide baseline information concerning the present vegetation and forest productivity of Lease 22 using an approach similar to that used on the adjacent Lease 17 (Peterson and Levinsohn 1977). The specific objectives are:

1) To classify the vegetation on the basis of floristic composition, into reasonably uniform, mappable units;

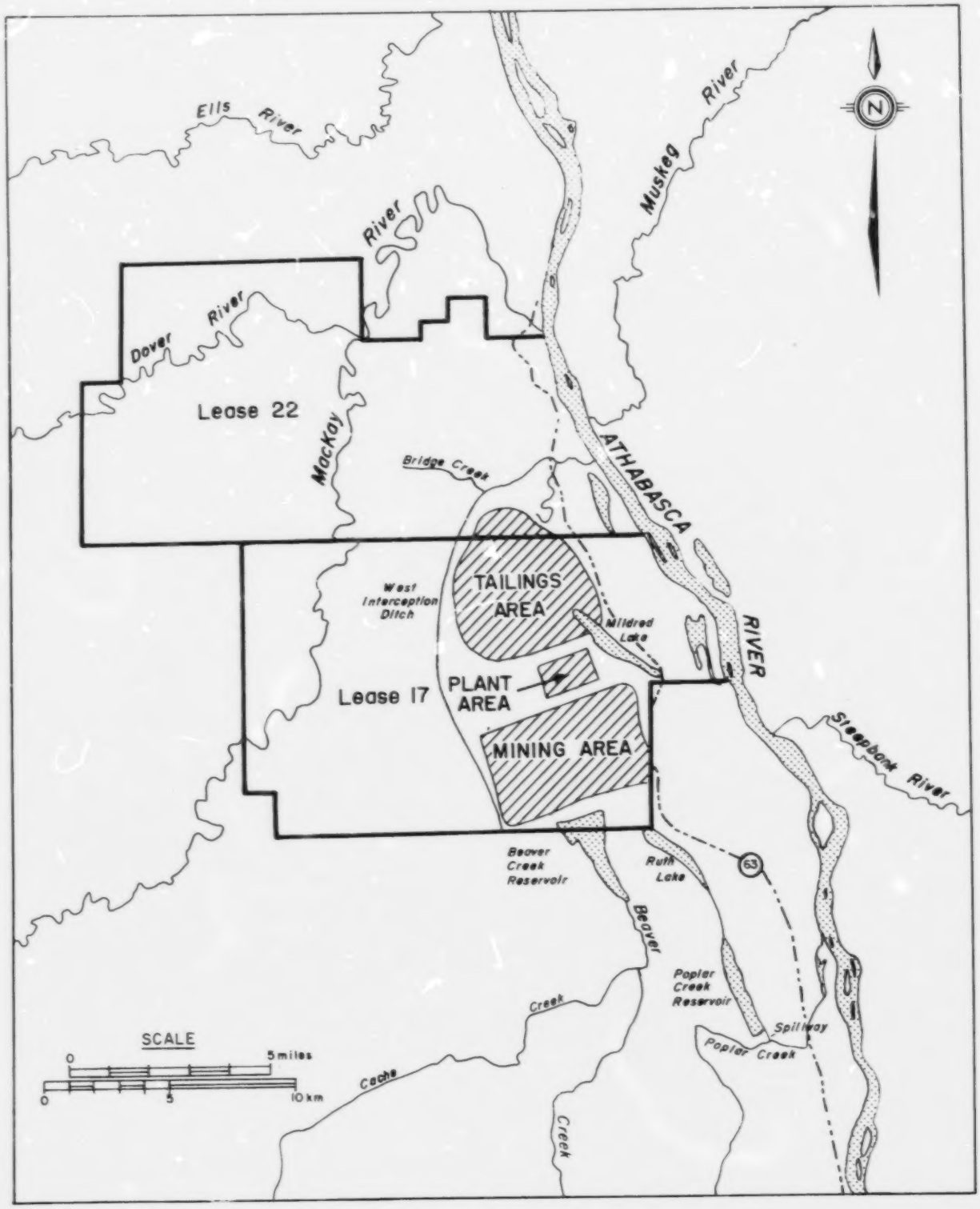
2) To describe the identified vegetation units according to tree, shrub, herb, and moss layers;

3) To map the described units at a scale of 1:20 000;

4) To calculate the area, occupied by each mapped vegetation unit;

5) To interpret and quantify the forest productivity of each vegetation unit for wood fibre production in accordance with the methods used by the Alberta Forest Service; and

6) To correlate the forest productivity data with available soils inventory data to evaluate land capability for forestry.



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LOCATION OF LEASE 22

Fig 1

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1.2 PLAN OF THE REPORT

The report is divided into three main sections. The first section describes the methods which were used in the photo analysis, field data collection, data analysis and mapping. The second section describes the vegetation in terms of species composition and cover; while the third describes the forest productivity of Lease 22 using tree volume, site index and mean annual increment which were then correlated with the soils map to assess the land capability for forestry.

2.0 METHODS

2.1 AIR PHOTO INTERPRETATION

The emphasis in this study was upon floristic classification, estimation of capabilities for wood fiber production and integration with soil studies to evaluate land capability for forestry. By using air photos as the basic mapping tool at 1:20 000, the vegetation units were defined on the basis of tree species and/or dominant shrub or herb cover. Understory differences associated with distinct microsites, but not visible on photos were not documented. Thus, for example, variations in plant communities described by Steen (1979) such as white spruce-aspen/low bush cranberry were not distinguished from white spurce-aspen/low bush cranberry - feathermoss.

Preliminary interpretation of black and white air photos, taken in 1980 at a scale of 1:20 000, was made prior to the field investigation. A 2 or 4 power Abrams stereoscope (CB-1) was used and boundaries of the major vegetation units were marked on the photographs.. The identification and distribution of the dominant tree species was aided by examination of the 1:15 000 Phase 3 forest cover maps. Potential sample sites representative of the vegetation types were selected on the basis of access by truck, helicopter and foot. Following this, a field reconnaissance was conducted from July 23 to 31, 1984.

2.2 FIELD DATA COLLECTION AND ANALYSIS

2.2.1 Vegetation

2.2.1.1 Data Collection

The air photo interpretation led to the identification of eleven vegetation types. A total of four samples for each type (44 sites) were selected for field sampling. The main selection criteria for sampling locations were that sites be relatively homogeneous and that they be within, rather than on the edge of an identified type. The location of each of the sampled sites was marked by a pin-hole on the appropriate air photo.

Plant species composition and cover within each site were obtained using a plotless sampling technique which consisted of a circular area 20 m in diameter located about a central sampling location. For dominant and conspicuous species, estimates of species cover were recorded for the radius readily visible to an observer standing at the central sampling point. The cover of less frequent species was noted while walking through a broader zone away from the central point, but still within the radius defined by prism selection of sample trees.

Data were recorded according to four basic vegetational layers, with subdivision of the A and B layers where necessary. The layers are defined as follows:

A layer: A1 dominant and codominant trees
A2 intermediate and suppressed trees

B layer: B1 saplings and shrubs, 2 to 9 m
B2 shrubs and woody plants, 15 cm to 2 m

C layer: small woody plants less than 15 cm tall and all herbaceous plants

D layer: mosses and lichens

A cover or significance value was estimated for each species in each layer. The species significance scale used was a combined rating of abundance and dominance based on the Domin-Krajina scale (Brooke, Peterson and Krajina 1970) as follows:

+ Species very sparse, dominance very small
1 Sparsely present, dominance small
2 Very scattered
3 Scattered to plentiful, dominance less than 1/20 of area visible to observer
4 Often present, dominance 1/20 to 1/10
5 Often present, dominance 1/10 to 1/4
6 Any number of individuals, dominance 1/4 to 1/3
7 Any number of individuals, dominance 1/3 to 1/2
8 Any number individuals, dominance 1/2 to 3/4
9 Any number of individuals, dominance over 3/4

Two additional notations were made for tree species: the symbol "*" denoted tree species present as seedlings only, as in the case of balsam fir; the letter "V" denoted a tree species present as a veteran, as in the case of white spruce at some locations.

In addition, the physical features of each site were noted in terms of slope, aspect, topographic position and drainage regime. Observations of disturbance factors such as previous fires, and animal or insect damage, as well as successional

status were made. Several photographs (35 mm) typical of major vegetation types were taken.

2.2.1.2 Data Analysis

The species and their significance values were summarized in tabular form by site according to the layers in which each occurred (Appendix A). Since many stands were even-aged, two tree and two shrub strata were not well defined, hence data were presented for the following layers:

Trees: all trees greater than 9 m, average of A1 and A2

Saplings: all tree species from B1, 2 to 9 m tall, are given significance values, an asterisk indicates the species seedlings the B2 or C layer

Shrubs: all shrub species average of B1 and B2, 15 cm to 2 m tall

Herbs and dwarf woody plants: less than 15 cm tall

Mosses and lichens: ground cover

Within each layer species were listed in descending order of significance ratings. For simplicity only those species of herbs and dwarf shrubs which occured in 2 or more sample sites and which had an average significance rating of 1 or more were included. Thus, by scanning the first few species of Appendix A, the characteristic composition of a given vegetation type is evident.

An alphabetical listing of all vascular plants observed on Lease 22 during the study is provided in Appendix B. This list includes species that were dropped from Appendix A as

well as those observed on Lease 22, but not within the selected sample sites. This table is not a complete listing of the flora of Lease 22 as this was outside the scope of the study.

2.2.2 Forest Productivity

2.2.2.1 Data Collection

Forest productivity data were obtained for 8 of 11 vegetation types and provided mensurational data for 32 of 44 sample locations. Data was not obtained for sedge-reed grass, willow reed grass, and river alder-tall willow types as tree cover was generally absent. Following description of floristic composition and cover, three estimates of basal area were made at temporary sampling points irregularly spaced along a 30-50 m transect which ran through the central sample location. Trees tallied at each imaginary "subplot center" were not in adjacent subplots. A wedge prism with a basal area factor of 2 (ie. 2.0 m^3/ha) was used in all stands to tally all "in" living trees having diameters at breast height (1.3 m) (DBH) greater than 1.1 cm following Alberta Forest Service (1983) procedure. At each basal area sampling point the number of trees showing stem overlap when viewed through the prism were recorded for each species present. Of the tallied dominant and codominant trees, three or four were selected as representative of average diameter, height, form, and species composition, and were measured for DBH and total height, and bored to determine stand age. Data from sample trees together with tree counts from prism sweeps provided the base for basal area and volume calculations.

2.2.2.2 Basal Area and Volume Calculations

Basal areas (BA) were computed for deciduous, coniferous and total tree cover by averaging the three subplot estimates to provide one stand estimate and using the formula below:

$$BA,\ m^2/ha = \frac{\text{mean no. of trees tallied by prism count}}{\text{No. of sampling sites (stands)}} \times BAF \quad (1)$$

Where: BAF = basal area factor of prism (2.0)

Volumes were computed for sample trees using formulas and regression coefficients developed by the Alberta Forest Service (AFS) from tree-section data obtained in Volume Sampling Region (VSR) 8 (Athabasca and Lac La Biche Forests) and were those used to derive Phase 3 inventories (Alberta Forest Service, in press).

The basic formula for gross volume of individual trees is:

$$GV,\ m^3 = aD^bH^c \quad (2)$$

Where:
GV = gross or total tree volume from ground to tip, m^3
D = DBH outside bark, cm
H = total tree height from ground to tip, m
a, b, c = regression coefficients for each species as established by the AFS for VSR 8.

The only species encountered for which regression coefficients were not available were balsam fir and white birch; coefficients for white spruce were used for balsam fir and those for aspen were used for white birch to determine approximate volumes. To compute volume on a stand basis for deciduous and coniferous components, individual tree volume

values of sample trees were applied to all tallied trees of a given species and component as follows:

$$\text{GV, } m^3/ha = \left(GV_{spl} \times \frac{BAF}{7.854 \times 10^{-5} D^2_{spl}} \times n_{spl}\right) \quad (3)$$

$$+ \left(GV_{sp2} \times \frac{BAF}{7.854 \times 10^{-5} D^2_{sp2}} \times n_{sp2}\right)$$

$$+ \ldots\ldots \text{ to spn}$$

Where: GV_{spl} = individual tree volume as defined in equation (2)

Basal Area Factor/$0.00007854D^2$ = expansion factor, which is used to adjust the basal area of the stand according to the average tree size

Where BAF of prism = 2.0 and D = DBH outside bark, cm

Deciduous and coniferous gross volumes were then summed to give total or gross volume for each stand.

Merchantable volumes were computed using AFS formulas, VSR 8 coefficients, and Phase 3 merchantability specifications for small roundwood. Thus merchantable volumes are cubic meters from a 0.3 m stump height to a 7.0 cm merchantable top diameter inside bark for all trees with DBH outside bark greater than 12.4 cm (Alberta Forest Service 1981). No estimates of cull due to stem decay or allowances for breakage were deducted in the conversion of gross volume; therefore merchantable volume in the formula used below is more correctly gross merchantable volume:

$$GMV, m^3/ha = GV\ (MR) \quad (4)$$

Where GMV = gross or total merchantable volume, m^3/ha
GV = gross or total volume as defined in equation (3)
MR = merchantability ratio calculated as:

$$MR = a + bG + cG^2 \quad (4a)$$

Where: a, b, c = regression coefficients for each species as established by the AFS for VSR 8; and

$$GV = \frac{(1-hs)^2}{H} - \frac{(Dtop)^4}{D} \quad (4b)$$

Where: hs = stump height, 0.3 m
H = height from ground to tip, m
Dtop = diameter inside bark at the merchantable limit, 7.0 cm
D = DBH outside bark, cm

It should be noted that AFS volume formulas and coefficients as well as the minimum tree size for merchantable volume used by Peterson and Levinsohn (1977) in their forest inventory of the west part of Syncrude's Lease 17 differ from those used here. In the absence of region specific regression equations, the volume estimates derived by Peterson and Levinsohn (1977) are based on modified formulas and species coefficients from Horner (1967). Merchantable volumes on Lease 17 were calculated using a stump height of 0.3 m (1 ft) and top diameter inside bark of 7.0 cm (3.0 inch) for all trees over 9.1 cm (3.6 inch) DBH outside bark (Peterson and Levinsohn, 1977).

2.2.2.3 Site Index and Mean Annual Increment Calculations for Land Capability

Site index, one measure of land capability for forestry, was calculated for one or more codominant species in a stand. A codominant species must provide at least 10% of the total

number of overstory stems. Sample trees used for calculations had reliable ages based on rot-free cores. Newly available site index formulae derived from Phase 3 sampling in VSR8 were provided by the AFS and enabled calculation of site index (reference age 50 years at breast height) as a function of total height and age at breast height (1.3 m) as follows:

For White Spruce:

$$SI,m = (1.3 + a) + (b \times (H-1.3)) + (c \times a \times LogA) - (d \times (LogA)^2) + (e \times (H-1.3)/A) + (f \times Log(H-1.3)) \quad (5a)$$

For Jack pine:

$$SI,m = (1.3 + a) + (b \times (H-1.3)) - (c \times ((LogA)^2)) + (d \times A \times LogA) + (e \times (H-1.3)/A) - (f \times (H-1.3) \times Log(H-1.3)) \quad (5b)$$

For Aspen:

$$SI,m = (1.3 + a) + (b \times (H-1.3)) + (c \times LogA) - (d \times (LogA)^2) + (e \times Log(H-1.3)/A) \quad (5c)$$

For Black spruce:

$$SI,m = (1.3 + a) + (b \times (H-1.3)) - (c \times (LogA)^2) + (d \times (H-1.3)/A) - (e \times (H-1.3) \times Log(H-1.3)) \quad (5d)$$

Where, for equations (5a) to (5d):

SI = site index, m
A = age at 1.3 m, years
H = height, m
a, b, c, d, e, f = regression coefficients for each species as established by the AFS, for VSR8
Log = natural logarithm base e

Site index was then rated according to AFS Phase 3 classes as follows:

SITE CLASS	SITE INDEX (HEIGHT AT STUMP AGE 70)	
	All Species Except Black Spruce	Black Spruce
Good	greater than 20 m	greater than 12 m
Medium	15-20	9-12
Fair-Poor	less than 15 m	less than 9 m

As one of the major objectives of this study was to determine land capability for forestry according to the Alberta Land Inventory (ALI) system, it was desirable to determine average merchantable mean annual increment (MAI) at age 100 for stands of a type in order to assign a capability class (Archibald et. al 1979). However, criteria for locating sample plots according to the ALI system requires placement of plots in stands of age 80 to 140 years which have greater than 50% of their volume in softwoods and a basal area of more than 34 m^2/ha (150 ft^2/ac) at age 100 (Prokopchuk and Archibald 1976). All but three sampled stands on Lease 22 (nos. 30, 36, 42 in the white spruce-aspen type) were either of recent fire origin and thus too young (30-50 years old); or were not burned recently and thus were too old (144-188 years); or were primarily deciduous stands deficient in softwood volume and/or basal area. Hence, capability classes could not be assigned based on average merchantable MAI at age 100.

For the 3 stands that met ALI plot location criteria, present gross merchantable volumes, total ages, and white spruce site indices were calculated according to ALI methods and used with supplied MAI curves to determine MAI at age 100 (Archibald et al 1979). Since gross merchantable volumes (GMVs) determined

using ALI methods (ie. using the white spruce standard volume table of Blyth (1952)) were only slightly greater for the three stands than present GMVs calculated using AFS formulae (equations (3) and (4)) and made little difference to the capability class assigned, the AFS form of GMV was used to calculate MAIs for all stands with merchantable components as follows:

$$MAI, \ m^3/ha = GMV/A \qquad (6)$$

Where: MAI = mean annual increment, present gross merchantable stand basis, m^3/ha
GMV = gross merchantable volume as in equation (4), m^3/ha
A = total present age, years

MAIs calculated using equation (6) were averaged for all stands of a forest type and the average MAI used to assign the type's capability class. The capability classes were assigned on the basis of the following ranges of MAI:

Class	MAI ($m^3/ha/yr$)
1	greater than 7.8
2	6.4 to 7.7
3	5.0 to 6.3
4	3.6 to 4.9
5	2.2 to 3.5
6	0.8 to 2.1
7	less than 0.7

MAIs were also calculated on a present gross volume basis (equation (3)) for comparison of resultant capability classes. Their use resulted in few changes therefore, they are not presented.

2.3 MAP PRODUCTION

Following the field survey, the preliminary interpretation on the air photos was checked and corrected as necessary. The type lines and annotation were then transferred to 1:20 000 scale base mosaics of Lease 22.

On the vegetation map, the smallest unit is about 0.5 ha. Recognizable vegetation units that were homogeneous but too small to map at 1:20 000 were handled in one of two ways. If several small vegetation types occurred in association with each other to form a recurring pattern, the group of associated types was mapped as one unit. An example is the aspen-birch vegetation type which is made up of small areas of aspen, small patches of black spruce and other areas of birch or willow cover, none of which, by themselves, are large enough to map at 1:20 000.

A different approach was used for small, homogeneous, vegetation units that existed only as isolated occurrences within larger vegetation types. For example, throughout the study area there are small pockets of willow - reed grass within other larger vegetation types. Only the largest of these willow-reed grass areas could be mapped as a distinct type at a scale of 1:20 000. Where they occurred as isolated patches within other vegetation types, such occurrences were considered to be too small and were not mapped.

The area of each mapped vegetation unit was measured using a computerized digitizer. The area of each unit was noted on the vegetation map along with the locations of each of the 44

sample sites. Aggregate areas of each of the eleven vegetation types were computed and summarized in tabular form.

3.0 VEGETATION TYPES OF LEASE 22

The predominantly forest vegetation of Lease 22 is part of the Mixedwood Section of the Boreal Forest Region (Rowe 1972). This section is characterized on upland sites by mixed forests with varying proportions of aspen, white spruce, balsam poplar, balsam fir and white birch. Aspen typically dominates young forests on recently burned sites, while white spruce dominates mature forests which have escaped recent disturbance. Jack pine occurs locally on dry sandy sites and forms a mixture with black spruce on the level tops of some higher hills. Black spruce and larch muskeg occur in depressions and poorly drained flats.

Development of the Athabasca oil sands in northeastern Alberta has resulted in several inventory studies of vegetation. The most comprehensive description of vegetation types was prepared by Stringer (1976) who, on the basis of structure and understory composition, identified 12 major types in the Alberta Oil Sands Environmental Research Program (AOSERP) study area. With some modification, Stringer's (1976) vegetation classification was used in a comprehensive biophysical inventory and mapping program (Thompson 1979, Thompson et al 1978), based on interpretation of false color infrared aerial photography at a scale of 1:60 000. A portion of these maps were ground checked in the Fort Mackay area by Steen (1979), who subdivided some major vegetation types on the basis of understory composition in order to enhance the vegetation detail.

As part of a wildlife habitat evaluation, Syncrude (1973) described and mapped 11 vegetation types on Lease 17, using

dominant tree species and principal shrubs important for browse. In a later report dealing primarily with potential revegetation species, Syncrude (1975) briefly described 8 main vegetation types on Lease 17, also based on major tree or shrub species. The most detailed description of vegetation and forest productivity of Lease 17 was prepared by Peterson and Levinsohn (1977), who mapped eight vegetation types basically following the classification system developed by Stringer (1976).

3.1 MAJOR VEGETATION TYPES

The eleven vegetation types of Lease 22 are described in a sequence along a moisture gradient from poorly drained to well drained. The vegetation types range from sedge and shrub covered wetlands, through open coniferous forests on organic soils to closed mixed coniferous and deciduous forests on upland mineral soils. The location and extent of each of the types is shown on Maps 1 and 2 (map pocket). Data on species composition and cover for each of the 44 sampling sites is presented in Appendix A. A list of latin and common plant names of the 165 vascular species encountered on Lease 22 is found in Appendix B. Species names follow Moss (1959) for vascular plants, Hale and Culberson (1970) for lichens, and Crum et al (1973) for mosses. A map of the vegetation of Lease 17, redrawn from Peterson and Levinsohn (1977) is included as Map 3.

The following descriptions of each type emphasizes the floristics and structure but also includes notes on successional status and site conditions. The vegetation can be broadly considered to characterize three distinct site

conditions based on landform and soil. A summary of the typical vegetation types, landforms, drainage regime, soils and forest capability classes for each of the three sites (wetlands, uplands and the MacKay River valley) is illustrated on Figures 2 to 4.

Photographs illustrating most of the major types are found in Peterson and Levinsohn (1977) except for aspen-jack pine and white spruce-balsam fir which are found in Appendix C.

3.1.1 Sedge-Reed Grass

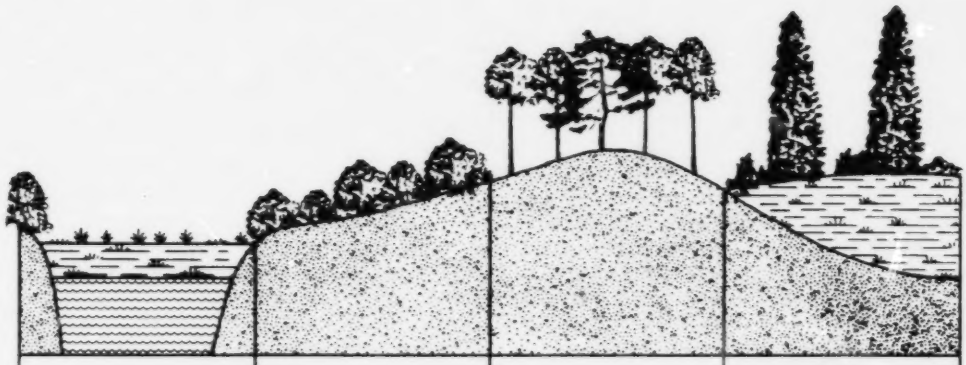
This type is characterized by sedge and reed grass stands up to 1 m high. The primary species are:

Shrub: 3%
- willow

Herb and Dwarf Shrub: 75%
- sedge
- reed grass
- marsh cinquefoil
- bedstraw
- common duckweed

Moss: 10%
- brown moss (Drepanocladus aduncus)

The sedge-reed grass meadow is scattered throughout the lease area along stream channels which have been dammed by beaver, in some abandoned channels in the floodplain above the MacKay and Athabasca rivers, and along drainageways in extensive areas of bog. The soils are very poorly drained organics which may often form a floating layer over deeper water bodies. The watertable at or near the surface throughout the



VEGETATION TYPE	SEDGE - REED GRASS	WILLOW - REED GRASS	ASPEN - BIRCH	BLACK SPRUCE -LABRADOR TEA
LANDFORM	BEAVER POND	LEVEL GLACIOLACUSTRINE PLAIN		DOMED BOG
DRAINAGE	VERY POOR	POOR	IMPERFECT	VERY POOR
DOMINANT SOIL	HYDRIC FIBRISOL	PEATY REGO GLEYSOL	ORTHIC GRAY LUVISOL	TYPIC MESISOL
FOREST CAPABILITY CLASS	–	–	6	7

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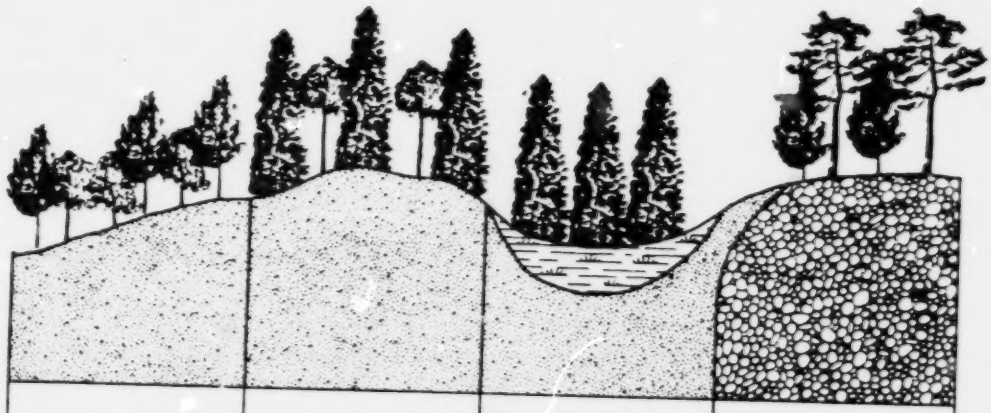
TYPICAL VEGETATION OF WETLAND AREAS

FIG 2



VEGETATION TYPE	ASPEN - BIRCH	ASPEN - WHITE SPRUCE AND WHITE SPRUCE -ASPEN	BLACK SPRUCE -FEATHERMOSS	ASPEN- JACK PINE
LANDFORM	LEVEL CLACIO-LACUSTRINE PLAIN	UNDULATING GLACIOLACUSTRINE AND GLACIOFLUVIAL PLAIN		GLACIOFLUVIAL PLAIN
DRAINAGE	IMPERFECT	MODERATELY WELL	POOR	WELL
DOMINANT SOIL	ORTHIC GRAY LUVISOL		PEATY REGO GLEYSOL	ELUVIATED DYSTRIC BRUNISOL
FOREST CAPABILITY CLASS	6	5	7	6

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TYPICAL VEGETATION OF UPLAND AREAS

FIG 3

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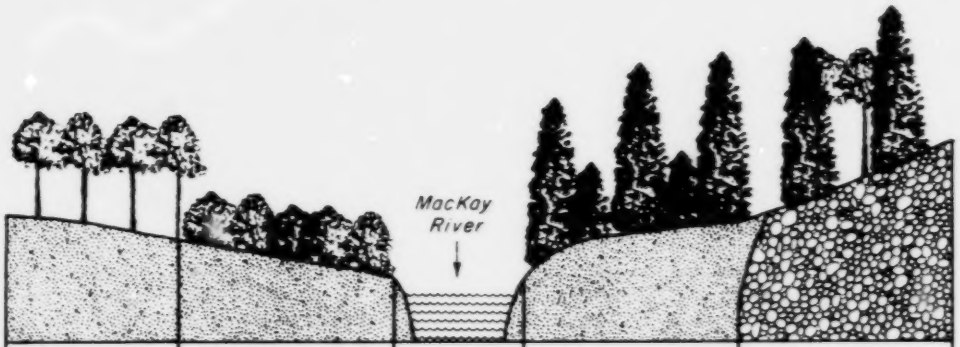

VEGETATION TYPE	BALSAM POPLAR-ALDER	RIVER ALDER-TALL WILLOW		WHITE SPRUCE -BALSAM FIR	WHITE SPRUCE -ASPEN
LANDFORM	ALLUVIAL POINT BAR			FLUVIAL TERRACE	COLLUVIUM
DRAINAGE	MODERATE	IMPERFECT		MODERATE	MODERATELY WELL
DOMINANT SOIL	GLEYED CUMULIC REGOSOL			CUMULIC REGOSOL	REGOSOL
FOREST CAPABILITY CLASS	4	–		5	5

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TYPICAL VEGETATION OF THE MACKAY RIVER VALLEY

FIG 4

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growing season probably is the major factor inhibiting the invasion of woody species, although fires during dry years may also be important. Stands of willow-reed grass, aspen-birch and black spruce-Labrator tea are often found in association with these wet meadows. These meadows occupy less than 2% of the total area (318 ha) of the lease (Table 1).

3.1.2 Willow-Reed Grass

This type typically consists of clumps of willow 2 to 3 m high scattered over a reed grass meadow. The primary species are:

Shrubs: 50%
- willow
- river alder

Herb and Dwarf Shrub: 60%
- reed grass
- sedge
- marsh cinquefoil

Moss: 5%
- brown moss (Campylinum stellatum)

This shrub type is found adjacent to the sedge meadows along the edges of beaver ponds and covering depressional areas in the bogs. The soils are poorly drained, fine grained, mineral and organic, where the water table is at the surface during much of the spring and early summer. Invasion of the type by black spruce is inhibited by high water tables and periodic fires. If the water table is raised due to beaver dams, the area will revert to a sedge-reed grass meadow. This type covering approximately 8% of the area is found scattered throughout the lease (Table 1).

TABLE 1

AREAS OF THE VEGETATION TYPES ON LEASE 22

Vegetation Type		Area (ha)	Approximate % of Total Map Area
I. Types without potential for forest productivity			
A. Sedge - Reed Grass		318	1.6
B. Willow - Reed Grass		1,517	7.8
C. River Alder - Tall Willow		6	0.1
D. Black Spruce - Labrador Tea		4,708	24.1
	Subtotal	6,549	33.5
II. Types with potential for forest productivity			
E. Aspen - Birch		3,041	15.6
F. Aspen - White Spruce		5,449	27.8
G. Aspen - Jack Pine		658	3.3
H. White Spruce - Aspen		1,300	6.7
I. White Spruce - Balsam Fir		200	1.0
J. Black Spruce - Feathermoss		891	4.5
K. Balsam Poplar - Alder		275	1.4
L. Logged		241	1.2
	Subtotal	12,055	61.5
III. Disturbed and Non-vegetated areas			
M. Clearings, Disturbed Areas, Roads		893	4.4
N. River		103	0.5
	Subtotal	996	100.0
	Total	19,600	100.0

3.1.3 River Alder-Tall Willow

The alder and willow of this type range in height from 4 to 8 m. The primary species are:

Shrub: 60%
- river alder
- willow
- red osier dogwood

Herb and dwarf shrub: 30%
- reed grass
- horsetail
- showy aster

This type is found on the point bars of the floodplains bordering the Mackay, Athabasca and Dover rivers. The soils are imperfectly drained Regosols made up of silt, sand and gravel. The water table is near the surface for most of the year, but varies depending on river levels. The shrub stands are naturally invaded by balsam poplar, however this process is limited by periodic flooding, sedimentation and ice scour which tends to reduce or eliminate the tree species. This is the first recognizable vegetation type adjacent to river banks and, due to the steep narrow valley, the type covers only a very small area of the lease.

3.1.4 Black Spruce-Labrador Tea

This open black spruce forest commonly referred to as bog or muskeg is characterized by stunted black spruce 4 to 9 m tall. The primary species are:

Tree and Sapling: 35%
black spruce

Shrub: 60%
Labrador tea
swamp birch

Herb and Dwarf Shrub: 20%
bog cranberry
cloudberry
three-leaved Solomon's seal

Moss and Lichen: 40%
peat moss (Sphagnum spp.)
brown moss (Aulacomnium palustre)
reindeer lichen (Cladina mitis)

The black spruce type occupies extensive areas of organic soil over the glaciolacustrine plain. The soils are very poorly drained, fibric to mesic in texture with permafrost in thicker organic deposits. Black spruce is considered to be the climax tree species of the bog and its succession is ensured through abundant regeneration by seeding and layering. As a result of previous forest fires, large areas of this type are covered by swamp birch and cottongrass. Associated on wetter soils are the sedge-reed grass and willow reed grass types, while on drier areas of mineral soil the aspen-birch type is found. In area, this black spruce type occupies 24% of the lease (Table 1).

3.1.5 Aspen-Birch

The trembling aspen and white birch which characterize this type are of variable density and have heights ranging from 8 to 15 m. The primary species are:

Tree and Sapling: 70%
- aspen
- white birch
- black spruce
- white spruce
- jack pine

Shrub: 20%
- prickly rose
- Canadian buffalo-berry
- willow
- Labrador tea

Herb and Dwarf Shrub: 35%
- bunchberry
- twinflower
- fireweed
- palmate-leaved coltsfoot

Moss and Lichen: 5%
- feather moss (Hylocomium splendens)
- reindeer lichen

The aspen-birch type occupies relatively a large area of the glaciolacustrine plain. The soils are silt and clay textured with imperfect drainage. This type is associated on wetter areas with the black spruce - Labrador tea forest and on drier areas with the aspen-white spruce forest. In the absence of forest fire many of these areas would become dominated by an aspen-white spruce forest. The amount of white birch in the type is low and appears to be declining as indicated by the abundance of top die-back due to a variety of factors including insects, disease and drought.

3.1.6 Aspen-White Spruce

The dominant aspen and white spruce of this closed forest range in height from 9 to 27 m, depending on stand age and moisture regime. The primary species are:

Tree and Sapling: 90%
aspen
white spruce

Shrub: 45%
prickly rose
willow
Canadian buffalo-berry

Herb and Dwarf Shrub: 20%
bunchberry
twinflower
palmate-leaved coltsfoot
wild lily-of-the-valley

Moss and Lichen: 15%
feathermoss (Hylocomium splendens and Pleurozium schreberi)

This type is the largest single vegetation unit of the lease occupying approximately 5400 ha or 28% of the area, being located on a broad band of glaciolacustrine plain bordering the MacKay and Dover rivers. The silt and clay textured soils are imperfectly to moderately well drained. The abundance of white spruce regeneration indicates a succession to a white spruce-aspen forest if fires do not interfere.

3.1.7 Aspen-Jack Pine

The dominant aspen and jack pine form a relatively closed forest 12 to 20 m high. The primary species are:

Tree: 70%
aspen
jack pine
white spruce

Shrub: 40%
blueberry
prickly rose
Canadian buffalo-berry

Herb and Dwarf Shrub: 20%
bunchberry
bog cranberry
twinflower
wild sarsaparilla

This type is found on glaciofluvial deposits in small isolated stands along either side of the MacKay and Dover rivers, and in larger stands along the west side of the Athabasca River. The site consists of well to rapidly well drained, fine to coarse sands. Succession is toward a white spruce dominated forest as shown by the abundant seedlings that originate from adjacent white spruce-aspen stands. The health of some of the dominantly pine stands near the Athabasca River is affected by natural dwarf mistletoe infection which has caused considerable witches-broom growth forms.

3.1.8 White Spruce-Aspen

A tall closed forest of white spruce and aspen with heights ranging from 20 to 35 m characterizes this type. The primary species are:

Tree and Sapling: 70%
white spruce
aspen

Shrub: 30%
low-bush cranberry
prickly rose
red osier dogwood

Herb and Dwarf Shrub: 40%
twinflower
bunchberry
horsetail

Moss and Lichen: 65%
feathermoss (Hylocomium splendens, Pleurozium schreberi and Ptilium crista-castrensis)

The white spruce-aspen forest is found mainly on glaciofluvial deposits just west of the Athabasca River and on glaciolacustrine deposits north of the Dover River and in the southwest portion of the lease. Small isolated stands occupy the banks and colluvial slopes along the Mackay River. Spruce forms the climax tree species in these stands although occasional balsam fir is present. The spruce, possibly mixed with fir, will ultimately dominate these stands as the aspen dies out, unless fires encourage the growth of aspen or pine. The large white spruce-aspen stand west of the highway to Fort MacKay has largely been logged, by a small local logging company, so that only small scattered blocks of trees remain.

3.1.9 White Spruce-Balsam Fir

The characteristic white spruce and balsam fir forms a tall closed forest ranging from 17 to 43 m in height. The primary species are:

Tree and Sapling: 70%
white spruce
balsam fir

Shrub: 25%
low-bush cranberry
prickly rose

Herb and Dwarf Shrub: 15%
bunchberry
twinflower
dewberry
bog cranberry

Moss and Lichen: 60%
feathermosses

The mixed spruce-fir type occupies small stands on alluvial terraces along the Athabasca, MacKay and Beaver rivers. The soils are well drained, however the sites are subject to periodic flooding and sedimentation during years of high river levels. The presence of white spruce and fir seedlings indicates that without major disturbances such as fire, the stands should be able to maintain their mixed character.

3.1.10 Black Spruce-Feathermoss

This type is made up of pure dense black spruce forest with heights ranging from 9 to 22 m. The primary species are:

Tree and Sapling: 65%
black spruce

Shrub: 10%
Labrador tea
willow

Herb and Dward Shrub: 15%
bog cranberry
twinflower

Moss and Lichen: 80%
feathermoss

The black spruce type covers small isolated depressional areas in the undulating glaciolacustrine and glaciofluvial plain.

The poorly drained soils generally consist of a layer of peat over silty clay or sand where the water table is near the surface for at least the first half of the growing season. Since most of the tree regeneration consists of black spruce, with rare white spruce, self perpetuation of this type is assured in the event of fire.

3.1.11 Balsam Poplar-Alder

A relatively dense, tall stand of balsam poplar with heights ranging from 14 to 24 m, and a tall understory of river alder characterizes this type. The primary species are:

Tree and Sapling: 80%
- balsam poplar
- aspen

Shrub: 45%
- river alder
- low-bush cranberry
- red osier dogwood
- willow

Herb and Dwarf Shrub: 40%
- horsetail
- tall mertensia

The balsam poplar forest occurs rarely in narrow bands on the point bars of the MacKay, Dover and Athabasca rivers. The silts and fine sands of the fluvial deposits are moderately well drained except during snowmelt and periods of high precipitation. The sites are subject to logging by beaver, annual flooding, sedimentation and erosion, and particularly along the Athabasca River - ice scour. Frequent balsam poplar seedlings and root suckers are a result of the annual disturbances to this type, however on slightly higher areas white

spruce seedlings begin to appear, indicating a possible succession to the white spruce - balsam fir forest. Due to the narrow river valleys, this type is often associated with the aspen-white spruce forest particularly where steep coluvial slopes border the floodplain.

3.2 COMPARISON WITH LEASE 17

The pattern of vegetation and floristics on both leases is very similar with the dominance of the black spruce-Labrador tea and the aspen-white spruce types. Three small vegetation types which were not reported for Lease 17 were found on Lease 22; two along the rivers, river alder-tall willow and white spruce-balsam fir, and one on the uplands, aspen-jack pine.

There is considerably more balsam poplar-alder on Lease 17 than on Lease 22. The interpretation of the type by Peterson and Levinsohn (1977) appears to have been broader including not only the point bars, but also the steep banks of the river valley. In this study, the balsam poplar-alder type was restricted to very narrow bands along the river often bordered by aspen-white spruce on the steep river banks. As a result the balsam poplar-alder area rapidly decreases when going from Lease 17 to 22.

The third area of difference is in the areas of sedge-reed grass and willow-reed grass. Comparisons with areas on Lease 17 shows that there is considerably more willow-reed grass in the drainage channels and beaver ponds, which is believed to be a reflection of the continued growth and expansion of the willow type over the past 7 years, as well as

changes to the beaver ponds including draining by natural means.

3.3 UNIQUE COMMUNITIES AND RARE SPECIES

The white spruce-balsam fir type that occurs along the MacKay and Athabasca rivers was not found on Lease 17. The relative uniqueness is based on the fact that this scarce type contains the largest (i.e. 43 m high and 57 cm DBH) and oldest (at 206 years) white spruce trees on the lease. The large size and age of these trees is due to the location of the stands along the river valleys where forest fires seldom occur. In a regional context, however, these stands are not rare or unique.

No rare plants, as defined by Argus and White, (1978) were found on the lease during the study.

4.0 FOREST PRODUCTIVITY OF LEASE 22

The forest productivity of Lease 22 is described in terms of the present standing volume as well as the potential or capability of the soils to produce trees. The tree data on which the volume and mean annual increments are calculated is given in Appendix D.

4.1 TIMBER VOLUME

The average gross merchantable timber volumes range from a high of 453 m^3/ha for the white spruce-balsam fir type to a low of 3 m^3/ha for the black spruce-Labrador tea type (Table 2). All of the forested types, except black spruce-Labrador tea are considered productive forest since the gross volume of all species exceeds 50 m^3/ha (Alberta Forest Service 1981). Thus, over 60% or approximately 12,000 ha of the lease is productive or potentially productive forest land. The white spruce-aspen and aspen-white spruce types contain over 75% (1,386,391 m^3) of the standing merchantable timber volume on the lease (Table 2).

4.2 SITE INDEX AND MEAN ANNUAL INCREMENT

The forests on the lease generally have a medium site index (Table 3). Although the average site index for the white spruce on the white spruce-balsam fir sites is poor, two of the sites are in the medium category. The white spruce-aspen sites are mostly medium with one poor index for white spruce; while the aspen-white spruce type had indexes ranging from poor to good for both aspen and white spruce.

TABLE 2

BASAL AREA, GROSS VOLUME AND MERCHANTABLE VOLUME FOR 31 FORESTED STANDS ON 8 FOREST VEGETATION TYPES WITHIN LEASE 22.

Stand No.	Basal Area (m2/ha)			Gross Volume (m3/ha)			Gross Mechantable Volume (m3/ha)			Total Merchantable	
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total	m3	%
WHITE SPRUCE-BALSAM FIR											
3	0	15	15	0	117	117	0	111	111		
5	4	25	29	46	263	309	45	254	299		
22	0	61	61	0	815	815	0	787	787		
41	0	52	52	0	631	631	0	614	614		
Mean	1	38	39	12	456	468	11	442	453	90 600	4.9
WHITE SPRUCE-ASPEN											
23	12	25	37	121	238	359	117	227	344		
30	10	28	38	132	346	477	129	336	464		
36	7	37	43	67	340	407	65	331	395		
42	7	35	41	53	359	413	51	347	398		
Mean	9	31	40	93	321	414	91	310	400	520 000	28.1
BALSAM POPLAR-ALDER											
25	43	0	43	250	0	250	220	0	220		
26	33	0	33	274	0	274	260	0	260		
28	35	0	35	179	0	179	152	0	152		
40	33	0	33	219	0	219	199	0	199		
Mean	36	0	36	230	0	230	208	0	208	57 200	3.1
ASPEN-WHITE SPRUCE											
1	7	7	14	51	61	111	48	58	107		
14	23	5	29	161	22	184	147	18	165		
24	23	4	27	136	18	154	126	15	140		
43	20	5	25	192	43	235	184	41	225		
Mean	18	5	24	135	36	171	126	33	159	866 391	47.1
ASPEN-JACK PINE											
8	8	14	22	48	121	170	43	112	154		
11	6	9	15	31	59	90	27	55	81		
12	0	17	17	0	95	95	0	89	89		
17	13	15	27	79	86	166	0	77	77		
Mean	7	14	20	40	90	130	18	83	100	65 800	3.5
BLACK SPRUCE-FEATHERMOSS											
6	0	28	28	0	183	183	0	169	169		
10	0	23	23	0	108	108	0	0	0		
29	0	33	33	0	155	155	0	0	0		
35	0	34	34	0	207	207	0	203	203		
Mean	0	30	30	0	163	163	0	93	93	82 863	4.5
ASPEN-BIRCH											
13	3	10	13	14	35	50	12	12	24		
19	9	5	14	49	26	75	24	23	47		
21	13	2	15	81	12	93	41	10	51		
39	9	11	20	54	50	104	43	31	74		
Mean	9	7	16	50	31	81	30	19	49	149 009	8.1
BLACK SPRUCE-LABRADOR TEA											
7	0	7	7	0	23	23	0	0	0		
15	0	0	0	0	0	0	0	0	0		
16	0	11	11	0	24	24	0	13	13		
18	0	5	5	0	11	11	0	0	0		
Mean	0	6	6	0	14	14	0	3	3	14 124	0.8
									TOTAL	1 845 987	100.0

7.666

TABLE 3

DOMINANT SOIL, SITE INDEX, MEAN ANNUAL INCREMENT, AND LAND CAPABILITY FOR FORESTRY OF THE FORESTED VEGETATION TYPES ON LEASE 22

Vegetation Type	Dominant Soil	Average Site Index* (species)	Average Mean Annual Increment (m^3/ha/yr)	Average Land Capability For Forestry Class	Percentage of Total Area	Weighted Mean Productivity (MAI x Area)
White spruce-balsam fir	Regosol	P - white spruce	2.8	5	1.0	2.8
White spruce-aspen	Orthic Gray Luvisol	M - white spruce and aspen	3.2	5	6.7	21.4
Balsam poplar-alder	Gleyed Cumulic Regosol	-	4.7	4	1.4	6.6
Aspen-white spruce	Orthic Gray Luvisol	M - aspen and white spruce	2.9	5	27.8	80.6
Aspen-jack pine	Eluviated Dystric Brunisol	M - aspen and jack pine	2.1	6	3.3	6.9
Black spruce-feathermoss	Peaty Rego Gleysol	M - black spruce	0.7	7	4.5	3.2
Aspen-birch	Orthic Gray Luvisol	M - white spruce, jack pine, and black spruce	1.1	6	15.6	17.2
Black spruce-Labrador tea	Terric and Fibric Mesisol	P - black spruce	0.1	7	24.1	2.4
Non Productive Forest					15.6	0.0
Average Productivity for Lease 22						1.41 m^3/ha/yr

* G - good
M - medium
P - poor or fair

A site index rating for the balsam poplar-alder type is not presented, since site index equations for balsam poplar have not been developed for Alberta.

The mean annual increment (MAI) of the forests on Lease 22 varies from a high of 4.7 m^3/ha/yr in the balsam poplar-alder type to a low of 0.1 m^3/ha/yr in the black spruce-Labrador tea type (Table 3). The most widespread and productive types, white spruce-aspen and aspen-white spruce, have average MAI's ranging from 3.2 to 2.9 m^3/ha/yr or class 5. Stands within these two types, namely 14 and 30, show higher capability in the class 4 category (3.6 to 4.0 m^3/ha/yr); while stand 1 is lower at class 6 (0.8 to 2.1 m^3/ha/yr). The weighted average MAI for the total lease area is 1.4 m^3/ha/yr or Class 6 (Table 3).

4.3 LAND CAPABILITY FOR FORESTRY

The highest land capability for forestry at class 4 is found in the small portions of the river valleys on poorly developed regosolic soils (1.4% of lease). The upland glaciolacustrine plains characterized by Orthic Gray Luvisols have a class 5 capability (50.1% of lease); while the well drained Eluviated Dystric Brunisols of the glaciofluvial plains have a lower capability at class 6 (3.3% of area). The capability of the wetland areas on poorly drained Gleysols and Mesisols is at class 7 (38.0% of area). The distribution of the dominant soils on Lease 22 and subsequently the land capability for forestry can be obtained by examining the soils report by Pedocan (1984).

The MAI's reported for Lease 17 for the white spruce-aspen and aspen-white spruce types are from 1.2 to 2.5 m^3/ha/yr (Peterson and Levinson 1977), are slightly lower than for similar types on Lease 22. The reasons for the differences are not clear but may be related to different methods of sampling and volume calculation, since the Lease 22 analysis is based on local volume tables not available in 1977, and on present gross merchantable volume rather than old boreal imperial AFS equations and old merchantable limits.

Comparison of productivity on Lease 22 as determined by this study, to that given by the Alberta Land Inventory (1977) map, shows that the capability reported herein is approximately one class lower, although the range of values in individual stands on the lease does meet the higher values given to the region. Differences are likely related to several factors including sample size, volume tables and methods of calculation. On Lease 22 the MAI is based on 32 stands over a 19.6 km^2 area, whereas the Alberta Land Inventory has 30 to 40 stands over the entire 13 200 km^2 map sheet. The volumes on Lease 22 are based on local (VSR8) species tables recently developed from the Phase 3 sampling; rather than the older spruce table from Blyth (1952) used by the Alberta Land Inventory for all species except pine. The methods of tree selection and site index calculation also varied from the Alberta Land Inventory approach as discussed in the methods (section 2.2.2.3).

5.0 SUMMARY

Syncrude Canada Ltd. holds the rights for surface mining of tar sands on Lease 22 located north of Fort McMurray on the west side of the Athabasca River. The objective of this study was to collect baseline information on the present vegetation and forest productivity of the lease to which post-mining forest cover and productivity can be compared. Methods used included field investigations, air photo interpretation, and calculation of forest productivity. Vegetation maps were prepared for both Lease 22 and for 17 (based on Peterson and Levinsohn 1977).

The vegetation of Lease 22 consisted of eleven major types which were each sampled by 4 stands, for a total of 44 sample sites. A total of 165 vascular species were observed. Aspen-white spruce was the dominant vegetation type covering nearly 28% of the 19,600 ha study area. The second most abundant vegetation type was black spruce-Labrador tea (24%) and the third was aspen-birch at 15%. The remaining 33% of the area was occupied by a complex mosaic of willow-reed grass, white spruce-aspen, black spruce-feathermoss, aspen-jack pine, sedge-reed grass, balsam poplar-alder, white spruce-balsam fir and river alder-tall willow types.

The distribution of the vegetation types is primarily controlled by the soil moisture regime. The imperfect to well drained uplands of the glaciolacustrine and glaciofluvial plain are covered by a variety of aspen-white spruce, white spruce-aspen and aspen-jack pine stands. The poorly drained depressional areas in the glaciolacutrine plain are dominated by black spruce-Labrador tea with aspen-birch and occasional

sedge-reed grass and willow reed grass types. The fluvial terraces and slopes of the MacKay, Athabasca and Dover rivers are characterized by a mixture of balsam poplar-alder, white spruce-balsam fir, white spruce-aspen and river alder-tall willow. Forest fires over the past 100 years have had an important influence on the pattern of vegetation, and the wetlands have been further affected by the accumulation of surface water from beaver dams along small streams.

The white spruce-balsam fir and white spruce-aspen types had the largest average merchantable volumes at 453 and 400 m^3/ha respectively. However based on total area the aspen-white spruce and white spruce-aspen contained 75% or approximately 1,386,000 m^3 of mercantable timber. Nearly two thirds of this merchantable volume is white spruce.

The average mean annual increment of the total lease area is 1.4 m^3/ha/yr. The mean annual increment at class 4 (3.6 to 4.9 m^3/ha/yr) was highest in the balsam poplar-alder type, and class 5 (2.2 to 3.5 m^3/ha/yr) in the extensive white spruce-aspen and aspen-white spruce types. In contrast the black spruce-Labrador tea and black spruce-feathermoss types had a capability of class 7 (less than 0.7 m^3/ha/yr).

The land capability for forestry was highest on the well drained uplands and on fluvial terraces and lowest on the wetlands. The Orthic Gray Luvisols of the glaciolacustrine and glaciofluvial plains have a capability of class 5; while the Eluviated Dystric Brunisols of the glaciofluvial plains are in class 6. Productivity on the Regosols of the river valleys ranged from class 4 to 5. At class 7, the poorly drained peaty Rego Gleysols and Terric and Fibric Mesisols of

the depressional portions of the glaciolacustrine plains were the least productive.

Forest productivity on Lease 22 was found to be slightly higher than on Lease 17, but approximately one class lower than mapped by the Alberta Land Inventory. The use of most current local volume tables and regression equations on Lease 22, as well as differences in sample size and methods of calculation were expected to be the major reasons for the differences.

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APPENDIX A

Plant Species Composition and Cover

APPENDIX A
PLANT SPECIES COMPOSITION AND COVER (SIGNIFICANCE RATINGS)

For 44 Stands on Syncrude Lease 22

VEGETATION TYPE	SEDGE-REED GRASS	WILLOW-REED GRASS	RIVER ALDER-TALL WILLOW	BLACK SPRUCE-LABRADOR TEA	ASPEN BIRCH	ASPEN-WHITE SPRUCE	ASPEN-JACK PINE	WHITE SPRUCE-ASPEN	WHITE SPRUCE-BALSAM FIR	BLACK SPRUCE-FEATHERMOSS	BALSAM POPLAR-ALDER
Stand	9 20 34 38	2 31 37 44	4 27 32 33	7 15 16 18	13 19 21 39	1 14 24 43	8 11 12 17	23 30 36 42	3 5 22 41	6 10 29 35	25 26 28 40
TREES											
Populus tremuloides					5 5 5 7	7 7 7 7	6 7 6	4 5 2 2	2 +		1 5 2 1
Picea glauca					1 4 V 2	5 2 2 2	2	7 7 5 6	7 6 7 7	4	7 6 7 6
Populus balsamifera					1 + +			1		1	
Picea mariana		+		3	4 2 2	1	4	3	2	7 7 8 5	
Betula papyrifera					1			+ 2			1 +
Pinus banksiana					2 2 1		5 2 5 6				
Abies balsamea								1	2 3		

SPECIES SIGNIFICANCE RATINGS

+ Very sparsely present, dominance very small
1 Sparsely present, dominance small
2 Very scattered, dominance small
3 Scattered to plentiful, dominance less than 1/20
4 Often present, dominance 1/20 to 1/10
5 Often present, dominance 1/10 to 1/4
6 Any number of individuals, dominance 1/4 to 1/3
7 Any number of individuals, dominance 1/3 to 1/2
8 Any number of individuals, dominance 1/2 to 3/4
9 Any number of individuals, dominance over 3/4
V Species present as veteran
• Species present as seedlings

VEGETATION TYPE	SEDGE-REED GRASS				WILLOW-REED GRASS				RIVER ALDER-TALL WILLOW				BLACK SPRUCE-LABRADOR TEA				ASPEN-BIRCH				ASPEN-WHITE SPRUCE				ASPEN-JACK PINE				WHITE SPRUCE-ASPEN				WHITE SPRUCE-BALSAM FIR				BLACK SPRUCE-FEATHERMOSS				BALSAM POPLAR-ALDER			
Stand	9	20	34	38	2	31	37	44	4	27	32	33	7	15	16	18	13	19	21	39	1	14	24	43	8	11	12	17	23	30	36	42	3	5	22	41	6	10	29	35	25	26	28	40
SAPLINGS																																												
Populus tremuloides														1			3	2	5	5	1	1	2	5	2	3	•	2	1	2	1	•	•	•	•					•	•	1	
Picea glauca																		5	1	3	1	3	2	4	2	4		3	3	3	3	3	1		2•		2				•	•	1	
Populus balsamifera									•	1	•	•					•	1		1			1				•														2	1	•	•
Picea mariana					•	•	1	1					7	3	6	7	5		7	•		2					5			2		•		1	2	3	3	2				
Betula papyrifera					1									•					5				1	•				•			2		•	1						•	•		
Pinus banksiana														1			1								1		•	1															
Larix laricina	•					•											+																											
Abies balsamea																													1				•	3	2	4								
SHRUBS																																												
Salix spp.	+	2	1	3	3	6	6	5	3	1	4	5			3	1	3	2	3	1	+	2	3	3			3	2	1		1	2					4	3	2	+	2	1	1	2
Ledum groenlandicum						1							8	7	4	8	3	4	1	1		2	1	3			5				2	5					7	2	6	1				
Rosa acicularis									1	3							2	3	4	2	4	1	4	5	2	2	3	4	4	5	3	2	1	5	2	2	2				4	1		2
Alnus crispa						1														2			•	3		5				1		1				1							
Shepherdia canadensis																	3	4	1	3	3	2	1	1	3		2	3		1	1	1	+			3					2			
Vaccinium myrtilloides																	4	1					+	2	3	4	4		3			•	3											
Cornus stonolnifer									1	3	2	3								•	1		•						2		2	1			2					2	3	2	2
Viburnum edule									1										1		1		1	4	2	•		1	4	3	5	4	1	5	2	3			1	8	4	4	5
Ribes oxyacanthoides										+													+						1		1	1			1				•		1	1	1
Amelanchier alnifolia																					4		1		1	4										•								
Betual pumila	2			+		1		5					2	2	8	5																												
Rubus strigosus																																										1	1	1
Alnus tenuifolia					5		5		7	7	5	5																											4		1	5	2	4
Lonicera dioica																					1			1			•		1										1		1		1	•
Symphoricarpus albus																				1	4				3	1							4										
Vaccinium uliginosum						•		•						1	2																													
Chamaedaphne calyculata									4		2																																	
HERBS & DWARF SHRUBS																																												
Cornus canadensis																	3	5	4	5	5	4	4	4	4	2	3	5	4	3	4	3	4	4		4	1		2		1	1		1
Vaccinium vitis-idaea													4	3	5	4	1	3		3		4	4			1	3	5			3	3	5		3		4	1	5	3				
Calmagrostis canadensis		8	2	1	4	2	5	5	3	2	4	2			2			2		1		2		4	2		1				2	4		4				2		•	1	1
Linnaea borealis																	2	3	2	2	5	1	3	2	1	1	2	3	4	5	2	4		4	3	4	1	2		2	2			

VEGETATION TYPE	SEDGE-REED GRASS				WILLOW-REED GRASS				RIVER ALDER-TALL WILLOW				BLACK SPRUCE-LABRADOR TEA				ASPEN-BIRCH				ASPEN-WHITE SPRUCE				ASPEN-JACK PINE				WHITE SPRUCE-ASPEN				WHITE SPRUCE-BALSAM FIR				BLACK SPRUCE-FEATHERMOSS				BALSAM POPLAR-ALDER			
Stand	9	20	34	38	2	31	37	44	4	27	32	33	7	15	16	18	13	19	21	39	1	14	24	43	8	11	12	17	23	30	36	42	3	5	22	41	6	10	29	35	25	26	28	40
Carex spp.	9	5	9	7	5	8	7	5																																				
Equisetum pratense											3				1												+	+										+	+	1				
Equisetum arvense																	1		+	1			1						2		4	5			3			4		5	1	3	6	5
Aralia nudicaulis																						4		4		2	3	1	2	5			4	3				+			7			
Epilobium angustifolium						1				+	2	+					1	3	2	1	1	2	1	1	3	3		1	+	1	1	1	2			+		1		2		4	2
Petasites palmatus										+							2	2	3	2		2	2	3	1			2		1	1	2					1	4		2				
Rubus pubescens																	1		+	1			1	2					3	1	2	1			1	1			2	2	2	1	1	1
Schizachne purpurascens									2	2	+						1		1	1	3		3	2		2			1	1		+	3	2	1	4					2			
Malanthemum canadense																	1			1	2	2	1	1	1	2		2	+	2	1		+	1	+	1			1	2				
Geocaulon lividum																		2		1	2	2	1	1	1	1	2	+					2		+	2	3		2		2			
Hertensia paniculata																													1												2	2	3	3
Potentilla palustris	4		4		1	2	2	1																																				
Vicia americana											2	2							+	+			+	+																				
Galium boreale						1				+	+						1	1				2	+	+						1	1	+			+						3		2	
Aster spp.						1	1	+	2	+	1	2								+			1	+	1		+		1												1		1	1
Fragaria virginiana										3								2	+	1		1	+	+							+			3				+			1	1		
Mitella nuda																																						+						
Typha latifolia		5		2		5																							1	1	1	1		2	1			1		1	+		1
Calla palustris		4	+			2																																						
Galium labradorium	2	1	1	1		2	+																																				
Equisetum fluviatile																																											
Cicuta bulbifera		2	+	1					2	+	2	3																															
Rubus acaulis						1																																					
Rubus chamaemorus					1		1						2	1		1									2			1															
Smilacina trifolia																																											
Lemna minor	2	1	2										2	1		1																											
Pyrola asarifolia																																											
Oxycoccus microcarpus													1		1	1									+								+	1	1				1	1				
Utricularia vulgaris	3										+																																
Lycopodium obscurum																	2	1																									
Eriophorum vaginatum													1	7															1												2	
Hippuris vulgaris			9		1																																						

VEGETATION TYPE	SEDGE-REED GRASS				WILLOW-REED GRASS				RIVER ALDER-TALL WILLOW				BLACK SPRUCE-LABRADOR TEA				ASPEN-BIRCH				ASPEN-WHITE SPRUCE				ASPEN-JACK PINE				WHITE SPRUCE-ASPEN				WHITE SPRUCE-BALSAM FIR				BLACK SPRUCE-FEATHERMOSS				BALSAM POPLAR-ALDER			
Stand	9	20	34	38	2	31	37	44	4	27	32	33	7	15	16	18	13	19	21	39	1	14	24	43	8	11	12	17	23	30	36	42	3	5	22	41	6	10	29	35	25	26	28	40
Achillea sibirica																			+				1								1						1							
Lathyrus ochroleucus																	1					1																						
Petasites sagittatus					1		1	1													1																				1			
Thalictrum spersiflorum									+																																3			1
Scutellaria galericulata	1		+				1												+																									
Poa sp.								4																																				
Apocynum androsaemifolium																					2																							+	
Taraxacum officinale										+	2																				+												
Pedicularis labradorica								+									2																											
MOSSES AND LICHENS																																											
Pleurozium schreberi													2				1	1	1	2	3	2	1		1			2	0		2	4	9	6	4	7		2	3	3	1		+	3
Hylocomium splendens															2		1	1	2	4	3	3	2	5				2	7	7	7	5		4	8	4	9	6	9	7				
Sphagnum spp.	3		+		2	1	+						5	3	2	3	1	3	2	4	3	3	2	5				2	7	3	7						4		1	4				
Ptilium crista-castrensis																								3					6						8	1	4							
Peltigera aphtosa															1	1	1	1	+	+			1	+	+		2				1		1	3					1				
Cladina mitis													8	1	1	8	1	2	1	1				+		+	9		+				+					5					
Aulacomnium palustre															6	1		1		2				+							+												
Dreparocladus aduncus	9		2	5			2	1																																1				
Campylium stellatum	2	1	2	1			2	2	+																																			
Polytrichum juniperum													2	5		1			+																			1	+					

APPENDIX B

List of Latin and Common Plant Names

LIST OF LATIN AND COMMON PLANT NAMES

The following lists alphabetically the 165 vascular plants observed on Syncrude Lease 22 during the study.

Abies balsamea (L.) Mill	Balsam fir
Achillea millefolium L.	Common yarrow
Achillea sibirica Ledeb.	Yarrow, milfoil
Actaea rubra (Ait.) Willd.	Red baneberry
Agropyron trachycaulum (Link) Malte	Slender wheat grass
Agrostis scabra Willd.	Hair grass
Alnus crispa (Ait.) Pur	Green alder
Alnus tenuifolia Nutt.	River, Mountain or thinleaf alder
Amelanchier alnifolia Nutt.	Saskatoon berry, service berry
Andromeda polifolia L.	Bog rosemary
Anemone canadensis L.	Canada anemone
Apocynum androsaemifolium L.	Spreading dogbane
Aralia nudicaulis L.	Wild sarsaparilla
Arctostaphylos rubra (Rehder & Wils.) Fern.	Alpine bearberry
Arctostaphylos uva-ursi (L.) Spreg.	Common bearberry, kinnikinnick
Arnica cordifolia Hook.	Arnica
Aster ciliolatus Lindl.	Lindley's aster
Aster conspicuus Lindl.	Showy aster
Aster foliaceus Lindl.	Aster
Aster laevis L. var. *geyeri* A. Gray	Smooth aster
Athyrium filix-femina (L.) Roth	Lady fern
Beckmannia syzigachne (Stevd.) Fern.	Slough grass
Betula glandulosa Michx.	Dwarf birch
Betula papyrifera Marsh.	White or paper birch
Betula pumila L. var. *glandulifera* Regel	Swamp birch
Bidens cernua L.	Nodding beggar-ticks
Bromus ciliatus L.	Fringed brome
Calla palustris L.	Water arum, wild calla
Calamagrostis canadensis (Michx.) Beauv.	Reed bent or marsh reed grass
Caltha palustris L.	Marsh marigold
Campanula rotundifolia L.	Bluebell, harebell
Carex aquatilis Wahlenb.	Sedge
Carex aurea nutt.	Sedge
Carex diandra Shrank	Sedge
Carex disperma Dewey	Sedge
Carex gynocrates Wormsk.	Sedge

Carex lasiocarpa Ehrh.	Sedge
Carex limosa L.	Sedge
Carex rostrata Stokes	Sedge
Carex vaginata Tausch	Sedge
Castilleja miniata Dough.	Common red paint-brush
Chamaedaphne calyculata (L.) Moench	Leather-leaf, cassandra
Cicuta bulbifer L.	Water hemlock
Cinna latifolia (Trev.) Griseb.	Drooping wood reed
Comandra pallida A. DC.	Bastard toad-flax
Cornus canadensis L.	Bunchberry
Cornus stolonifera Michx.	Red osier dogwood
Delphinium glaucum S. Wats	Tall larkspur
Deschampsia caespitosa (L.) Beauv.	Tufted hairgrass
Elaeagnus commutata Bernh.	Silver-berry, wolf willow
Elymus canadensis L.	Canada wild rye
Elymus innovatus Beal	Hairy wild rye
Empetrum nigrum L.	Crowberry
Epilobium angustifolium L.	Fireweed
Epilobium palustre L.	Willow-herb
Equisetum arvense L.	Common or field horsetail
Equisetum fluviatile L.	Horsetail, scouring rush
Equisetum pratense Ehrh.	Horsetail, scouring rush
Equisetum scirpoides Michx.	Horsetail, scouring rush
Equisetum sylvaticum L.	Woodland horsetail
Erigeron sp.	Fleabane
Eriophorum vaginatum L.	Cotton grass
Erysium cheiranthoides L.	Wormseed mustard
Festuca saximontana Rydb.	Saximontana fescue
Fragaria vesca L. var. americana Porter	Woodland strawberry
Fragaria virginiana Duchesne var. glauca S. Wats	Wild strawberry
Galium boreale L.	Northern bedstraw
Galium labradoricum Wieg.	Bedstraw or cleavers
Galium triflorum Michx.	Sweet-scented bedstraw
Geocaulon lividum (Richards.) Fern	Bastard toad-flax
Glyceria grandis S. Wats	Manna grass
Goodyera repens (L.) R. Br.	Rattlesnake plantain
Gymnocarpium dryopteris (L.) Newm.	Oak fern
Habenaria hyperborea (L.) R.Br.	Northern green orchid
Hedysarum boreale Nutt.	Hedysarum
Hieracium umbellatum L.	Narrow-leaved hawkweed
Hippuris vulgaris L.	Mare's-tail
Hordeum jubatum L.	Foxtail barley

Impatiens capensis Meerb.	Touch-me-not
Juncus balticus Willd.	Wire rush
Kalmia polifolia (Wang.) var. microphylla (Hook.) Rehd.	Mountain laurel
Larix laricina (Du Roi) K.Koch	Tamarack
Lathyrus ochroleucus Hook.	Pea vine
Ledum groenlandicum Oeder	Common Labrador tea
Lemna minor L.	Common duckweed
Linnaea borealis L. var. americana (Forbes) Rehd.	Twin-flower
Lonicera dioica L. var. glaucesens (Rydb.) Butters	Twining honeysuckle
Lonicera involucrata (Richards.) Banks	Bracted honeysuckle
Lonicera villosa (Michx.) R&S	Fly honeysuckle
Lycopodium annotinum L.	Stiff club-moss
Lycopodium clavatum L.	Common or running club-moss
Lycopodium complanatum L.	Ground cedar or creeping Jenny
Lycopodium obscurum L.	Tree club-moss or ground pine
Lycopus asper Greene	Water horehound
Maianthemum canadense Desf. var. interius Fern	Wild lily-of-the-valley
Matteuccia struthiopteris (L.) Todaro	Ostrich fern
Melilotus officinalis (L.) Lam.	Yellow sweet clover
Mentha arvensis L. var. villosa (Benth.) S.R. Stewart	Wild mint
Menyathes trifoliata L.	Buck-bean
Mertensia paniculata (Ait.) G. Don	Tall mertensia
Mitella nuda L.	Bishop's-cap or mitrewort
Moneses uniflora (L.) A. Gray	One-flowered wintergreen
Monotropa uniflora L.	Indian pipe
Myrica gale L.	Sweet gale
Oryzopsis asperifolia (Michx.)	Rice grass
Oxycoccus microcarpus Torcz.	Small bog cranberry
Parnassia palustris L. var. neogaea Fern.	Grass-of-Parnassus
Pedicularis labradorica Wirsing	Lousewort
Petasites palmatus (Pursh) A. Gray	Palmate-leaved coltsfoot
Petasites sagittatus (Pursh) A. Gray	Arrow-leaved coltsfoot
Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) BSP.	Black spruce
Pinus banksiana Lamb.	Jack pine
Poa sp.	Bluegrass

Polygonum amphibium L. var. stipulaceum (Coleman) Fern.	Water smartweed
Populus tremuloides Michx.	Aspen
Populus balsamifera L.	Balsam poplar
Potentilla fruticosa L.	Shrubby cinquefoil
Potentilla norvegica L.	Rough cinquefoil
Potentilla palustris (L.) Scop.	Marsh cinquefoil
Potentilla tridentata Ait.	Three-toothed cinquefoil
Prunus pensylvanica L.f.	Pin cherry
Prunus virginiana L.	Choke cherry
Pyrola asarifolia Michx.	Common pink wintergreen
Pyrola secunda L.	One-sided wintergreen
Pyrola virens Schweigg	Greenish-flowered wintergreen
Ranunculus gmelinii DC.	Yellow water crowfoot
Ribes oxyacanthoides L.	Wild gooseberry
Ribes triste Pall.	Wild red currant
Rorippa islandica (Oeder) Borbas var. fernaldiana But & Abb.	Yellow cress
Rosa acicularis Lindl.	Prickly rose
Rubus acaulis Michx.	Dwarf raspberry
Rubus chamaemorus L.	Cloudberry, baked-apple berry
Rubus pubescens Raf.	Dewberry, running raspberry
Rubus strigosus Michx.	Wild red raspberry
Rumex occidentalis S. Wats var. fenestratus (Greene) Le page	Western dock
Salix arbusculoides Anderss.	Willow
Salix bebbiana Sarg.	Beaked willow
Salix discolor Muhl.	Pussy willow
Salix glauca L.	Willow
Salix interior Rowlee	Sandbar willow
Salix myrtillifolia Anderss.	Willow
Schizachne purpurascens (Torr.) Swallen	False melic
Scirpus microcarpus Presl.	Small-fruited bulrush
Scutellaria galericulata L.	Common skullcap
Shepherdia canadensis (L.) Nutt.	Canadian buffalo-berry
Smilacina trifolia (L.) Desf.	Three-leaved Solomon's-seal
Solidago multiradiata Ait.	Solidago
Sparganium eurycarpum Engelm.	Giant bur-reed
Symphoricarpos albus (L.) Blake	Snowberry
Symphoricarpos occidentalis Hook.	Wolfberry or buckbrush
Taraxacum officinale Weber	Common dandelion
Thalictrum sparsiflorum Torez.	Flat-fruited meadow rue
Trientalis borealis Raf.	Star-flower

Trifolium repens L.	White or Dutch clover
Trigolchin maritima L.	Arrow-grass
Typha latifolia L.	Common cattail
Urtica gracilis Ait.	Common nettle
Vaccinium caespitosum Michx.	Dwarf bilberry
Vaccinium myrtilloides Michx.	Blueberry
Vaccinium uliginosum L.	Bog bilberry
Vaccinium vitis-idaea L. var. *minus* Lodd.	Bog cranberry
Viburnum edule (Michx.) Raf.	Low-bush cranberry
Viburnum trilobum Marsh.	High-bush cranberry
Vicia americana Muhl.	Wild vetch

APPENDIX C

Photographs

Figure 1. Aspen-jack pine vegetation type found on the uplands beside the MacKay and Athabasca rivers.

Figure 2. White spruce-balsam fir vegetation type found on fluvial terraces beside the MacKay River.

APPENDIX D

Tree Measurement Data

Tree Measurement Data for the sample trees in 31 stands in 8 vegetation types, Syncrude Lease 22.

Vegetation Type	Stand Number	Tree species	Mean Number of Trees /three prism sweeps	DBH (cm)	Height (m)	Total Age (years)
White Spruce-Balsam Fir	3	white spruce	7.3	31.3	22.1	136
		white spruce		25.8	17.5	121
		white spruce		30.9	20.3	141
	5	white spruce	12.3	29.1	26.8	132
		white spruce		30.8	29.7	136
		white spruce		32.8	26.5	163
		aspen	2.0	30.9	27.7	135*
	22	white spruce	25.7	56.8	43.0	174
		white spruce		39.2	36.0	185
		white spruce		46.6	35.0	206
		balsam fir	4.7	28.0	26.0	88*
	41	white spruce	23.3	44.4	34.1	149
		white spruce		34.7	28.5	130
		white spruce		47.9	35.6	174
		black spruce	2.7	42.3	32.7	156*
White Spruce-Aspen	23	white spruce	11.3	24.8	24.6	104
		balsam fir	1.0	26.8	24.1	83
		aspen	6.0	27.0	24.1	84
	30	white spruce	14.0	65.6	35.4	113
		white spruce		36.9	30.8	140
		white spruce		42.3	32.8	146
		aspen	5.0	48.3	33.0	124*
	36	white spruce	12.7	48.6	28.7	140
		white spruce		41.0	26.5	142
		white spruce		38.8	23.7	118
		black spruce	5.7	42.8	26.3	142*
		aspen	3.3	48.9	25.9	117
	42	white spruce	17.3	36.0	25.5	102
		white spruce		33.0	23.6	98
		whtie spruce		56.4	32.1	171
		aspen	1.7	30.5	19.8	H.R.
		birch	1.7	30.5	19.8	85

Tree Measurement Data for the sample trees in 31 stands in 8 vegetation types, Syncrude Lease 22.

Vegetation Type	Stand Number	Tree species	Mean Number of Trees /three prism sweeps	DBH (cm)	Height (m)	Total Age (years)
Balsam Poplar-Alder	25	balsam poplar	21.3	18.6	16.2	51
		balsam poplar		14.3	14.3	47
		balsam poplar		14.8	17.7	54
	26	balsam poplar	12.7	24.6	24.5	51
		balsam poplar		24.6	22.0	48
		balsam poplar		17.4	18.8	44
		aspen	4.0	22.2	21.8	48*
	28	balsam poplar	15.0	14.7	13.7	38
		balsam poplar		14.3	13.5	35
		balsam poplar		14.6	13.6	39
		aspen	2.7	14.5	13.6	37*
	40	balsam poplar	16.7	21.2	19.3	38
		balsam poplar		14.5	16.5	38
		balsam poplar		16.7	18.1	39
Aspen-White Spruce	1	aspen	3.7	28.6	17.3	80*
		white spruce	3.3	38.1	22.3	107
		white spruce		31.8	24.2	89
	14	white spruce	2.7	12.9	9.5	34
		aspen	11.7	15.2	15.0	29
		aspen		17.3	17.1	47
	24	white spruce	2.0	13.0	10.2	43
		aspen	10.3	20.7	15.9	38
		aspen		15.6	12.8	39
		birch	1.0	18.2	14.4	39*
	43	aspen	10.0	33.0	25.6	116
		aspen		31.4	27.0	125
		aspen		14.9	16.2	38
		white spruce	2.7	27.6	20.2	91

Tree Measurement Data for the sample trees in 31 stands in 8 vegetation types, Syncrude Lease 22.

Vegetation Type	Stand Number	Tree species	Mean Number of Trees /three prism sweeps	DBH (cm)	Height (m)	Total Age (years)
Aspen-Jack Pine	8	jack pine	7.0	15.4	20.6	45
		jack pine		17.9	18.2	41
		aspen	4.0	14.3	14.0	44
	11	jack pine	4.7	19.3	15.1	40
		jack pine		19.8	14.6	43
		aspen	3.0	13.8	12.1	37
	12	jack pine	6.3	23.1	11.8	95
		jack pine		23.5	16.1	98
		black spruce	2.3	16.7	13.4	73
	17	jack pine	7.3	13.0	13.4	40
		jack pine		18.1	13.3	40
		aspen	6.3	9.1	13.6	35
Black Spruce-Feathermoss	35	black spruce	17.0	28.2	20.1	150
		black spruce		45.0	22.2	181
		black spruce		20.8	18.1	131
	29	black spruce	16.3	10.4	10.1	125
		black spruce		10.9	10.2	144
		black spruce		10.5	11.5	140
	10	black spruce	11.7	7.1	10.1	54
		black spruce		10.5	9.0	55
		black spruce		7.2	8.9	52
	6	black spruce	14.0	18.0	16.0	124
		black spruce		16.5	17.1	130
		black spruce		14.8	14.3	130

Tree Measurement Data for the sample trees in 31 stands in 8 vegetation types, Syncrude Lease 22.

Vegetation Type	Stand Number	Tree species	Mean Number of Trees /three prism sweeps	DBH (cm)	Height (m)	Total Age (years)
Aspen-Birch	13	jack pine	1.3	21.5	11.4	39
		black spruce	2.7	12.2	8.3	48
		aspen	1.3	14.8	12.5	32
		white spruce	1.0	12.2	8.3	43*
	19	jack pine	1.0	14.0	12.4	40
		aspen	4.7	8.8	10.5	35
		aspen		12.5	13.0	43
		white spruce	1.3	14.0	13.4	47*
	21	aspen	6.7	12.3	12.1	45
		apsen		15.2	15.8	46
		white spruce	1.0	13.8	14.0	55*
	39	jack pine	1.3	15.5	10.5	40
		white spruce	2.0	17.2	13.5	46
		black spruce	2.0	10.4	8.9	50
		aspen	4.7	11.7	13.1	35
Black Spruce-Labrador tea	15	- - - - - - - - -	no trees tallied	- - - - - - - - -		
	7	black spruce	3.3	12.2	9.3	77
		black spruce		8.6	8.4	66
		black spruce		11.6	8.7	56
	16	black spruce	5.3	12.8	7.4	60
		black spruce		10.0	6.1	51
		black spruce		13.3	7.1	52
	18	black spruce	2.7	5.5	4.2	65
		black spruce		6.4	5.1	60
		black spruce		6.3	5.1	50

* estimated values of age in the case of heart rot or incomplete rings
H.R. Heart rot

MAPS
NOT
FILMED

CARTES
OMISES